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ASSESSING REFERENCE EVAPOTRANSPIRATION USING PENMAN-MONTEITH AND PAN METHODS IN THE WEST REGION OF AFGHANISTAN

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ABSTRACT: Optimal estimation of reference evapotranspiration (ET_0) is extremely important to calculate irrigation scheduling in Afghanistan. In this study, a measured evapotranspiration from an A-class pan (ET_{pan}) was selected as an index to discuss the error of ET_0 which was calculated using the Penman-Monteith (FAO-56PM) method in the west region of Afghanistan, which is exposed to extreme climate condition. Results obtained showed that the period from June to September was confirmed as extreme, with out-of-normal-range climatic data, for example, high temperature, low humidity, and relatively strong wind speed. While for the rest of the year, they were almost within the normal range of the climatic variables. By comparing the daily ave rage ET_0 and ET_{pan}, the differences between ET_0 and ET_{pan} were significantly large in the period from June to September, while this differentiation was very small outside of this period. By comparing the relationship of error with climatic variables, it was found that the relationship of the error with wind speed was strongest compared to the other three variables. The higher the wind, the larger the difference, and vice versa. Therefore, experimentally it was confirmed that this kind of error becomes larger when ET_0 is greater than 10 mm d^{-1}.

Keywords: Evapotranspiration, Pan evaporation, Error production, Climatic factors

1. INTRODUCTION

Spatial distribution of water availability is not uniform among the regions in Afghanistan. The western region, consisting of four provinces such as Herat, Farah, Badghis and Ghour province, is characterized with a semi-arid climate that has low precipitation, as the total precipitation was 345.6 mm in 2009. Many various factors cause agricultural water scarcity in the region, of which the high rate of ET_0 is one of the main factors.

The ET_0 in Herat has the highest rate compared to the other cities in Afghanistan, as the daily average value is above 10 mm d^{-1}, especially during the main season of crop growing [11]. One of the factors, among the all other factors which adversely affect the ET_0 in the west region, is a persistent wind locally known as “120-day winds”. From the literature, it is known that there is a great impact of wind speed in increasing ET_0, which can have profound implications for hydrologic processes and agricultural crop performance [3].

The “120-day winds” usually begin in early June and go on until late September with a great force 7 m s^{-1}, on average [11]. This period covers entire of the summer season, which is the main season of crop growing. According to the data measured in 2009, the precipitation is almost zero during the windy season and daily average temperature is as high as 17.5 °C.

Optimal estimation of ET_0 is extremely important as well as needed for the the planning of agricultural water distribution and irrigation scheduling in the west region of Afghanistan. For estimating ET_0, many different methods have been developed based on their daily performance under the given climatic condition worldwide, of which the FAO-56PM method was confirmed as the only method offering high accuracy when estimating ET_0 [1]. The FAO-56PM equation is a physically based approach which can be used without local calibration. This property demonstrates the robustness of the equation [24]. This method has been accepted by the international scientific community to estimate ET_0 [6, 14]. A comprehensive explanation regarding the development and computation of this method can be found in FAO paper 56.

Although the set of Penman equations are the most accurate methods, still there are some studies reporting low performance of these methods when calculating ET_0. Steduto et al. (1996) conducted research in Mediterranean locations using lysimeter data. They reported that FAO-56PM underestimated lysimeter data at high rates. Oudin et al. (2005) surprisingly found that the potential evapotranspiration based on the Penman approach seem less advantageous to feed rainfall–runoff models in France, Australia, and the United States. In a study, six well-known methods have been examined by Ganji et al. (2017) to estimate ET_0 for the west region of Afghanistan. By considering

ET_{pan} as an indicator, the FAO-56PM method was confirmed as the method closest to ET_{pan} among the six well-known models in the west region of Afghanistan.

Although the FAO-56PM method produced estimates closest to ET_{pan}, differences emerged between ET_0 and ET_{pan} when compared. In this paper, the FAO-56PM equation was examined with the aim to assess the performance of the FAO-56PM method under the climatic conditions of the west region of Afghanistan.

To examine the performance of the FAO-56PM equation, pan evaporation data was used. Although there is no unique approach for model evaluation, the evaporation pan data has been used as an index of evapotranspiration and for estimating lake and reservoir evaporation [16]. A study in China selected evaporation pan data to evaluate the spatial and temporal difference of monthly reference evapotranspiration using the Penman-Monteith method. The results showed that pan measurements display a consistent regional pattern, and the temporal variability of reference evapotranspiration is much better represented by pan measurements [7]. Xu (2000) evaluated eight radiation-based equations for determining evaporation using pan evaporation measured data as the indicator at the Changins station in Switzerland.

Pan evaporation is related to the reference evapotranspiration by an empirically derived pan coefficient. The empirically derived coefficient k_p is a correction factor which depends on the prevailing upwind fetch distance, average daily wind speed, and relative humidity (RH) conditions associated with the sitting of the evaporation pan [4].

The k_p ranges from 0.35 to 0.85, depending on deferent conditions [1]. Many various equations have been presented for calculating the k_p throughout the world, but those equations cannot compatibly cover the effective environmental factors on k_p, as local estimation is necessary for estimating the accurate value of ET_0. In this study, five different equations were used to estimate k_p. The proposed equations have been tested in different climatic conditions worldwide as they showed different results. Singh et al. (2014) reported that the modified Snyder model has a very close agreement with the FAO-56PM, and he recommended this model as the best model for computation of ET_0 for a semi-arid region. Sabziparvar et al. (2010) reported that the Snyder and Orang models were the best-fitted models for a warm arid climate. Another study, conducted by Conceição (2002) in the northwest region of the São Paulo State, Brazil, reported that ET_0 estimated using k_p determined by the Snyder equation presented the best regression coefficients when compared to the Penman-Monteith method. Gundekar et al. (2008) found that the Snyder (1992) model was the best model for the semi-arid region of India. Sentelhas and Folegatti (2003) indicated that the best k_p models to estimate ET_0 were Cuenca (1989) models, for a semi-arid region in Brazil.

The purpose of this study is showing the critical period for the accurate calculation of ET_0using the FAO-56 PM method when making an irrigation plan.

2. METHODS AND DATA

2.1 Study Area

Herat province in the west region of Afghanistan was selected as the study area. The main research center in the study area is Urdu Khan Research Farm with a total area of 225 hectares, located at a latitude of 34° 19′ N and a longitude of 62° 16′ E, with an elevation of 964 meters, in Urdu Khan village, at 5.8 kilometers southeast of Herat city [19] Fig. 1.

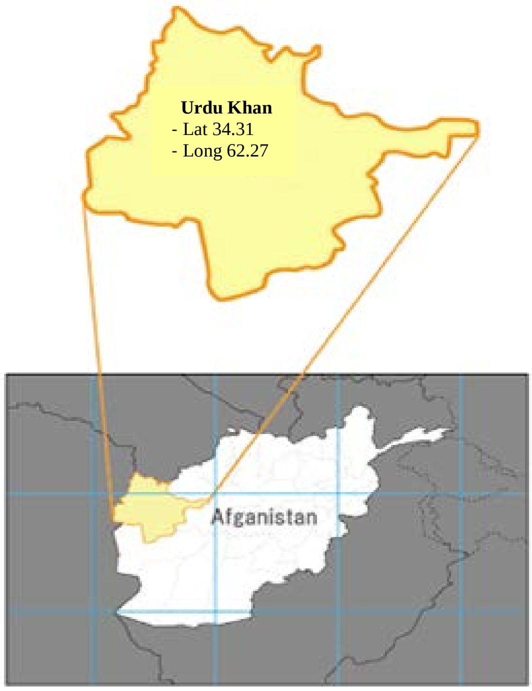

Fig. 1 Location of Urdu Khan Research Farm in Herat, Afghanistan

A unique phenomenon in the study area is a persistent wind during the summer season, which is locally known as "120-day winds". The "120-day winds" coincide with the summer season (the main season of crop growing), which has a profound impact on ET_0 rate. According to the data from 2009, the average wind speed during the "120-day winds" was 3.4 m s^{-1}. While in the rest of the year (out the windy period), the average was approximately 1.5 m s^{-1}. The general classes of monthly wind speed, from light wind ($\leq$ 1.0 m s^{-1})

to moderate (> 1.0 m s^{-1}), are listed in FAO paper 56.

2.2 Climatic Data

The climatic data of wind speed (u_2), net radiation (R_n), temperature (T) and relative humidity (RH) were obtained using numerous sources in 2009, listed in Table 1. As stated earlier, the main center to record meteorological data is Urdu Khan Research Farm. This center is operated by the Agricultural, Irrigation and Livestock Department in Herat province of Afghanistan. The center is the only research center in the west region which is used for research related to agriculture and livestock. In 2016, the research center was re-equipped with modern devices for measuring climatic data. Prior to 2016, the station was facing data scarcity as well as low quality data. To reduce the error which would be caused by missing or low-quality data, we used accessible online databases as supplements for missing and low-quality data.

2.3 Computation Procedure

2.3.1 Estimation of ET_0

The FAO-56PM equation (Eq. (1)) was used to estimate ET_0. This equation was confirmed as the only method offering high accuracy when estimating ET_0 [1].

$$\boldsymbol{ET_0} = \frac{\mathbf{0.408}\Delta(\boldsymbol{R_n} - \boldsymbol{G}) + \gamma \dfrac{\mathbf{900}}{\boldsymbol{T} + \mathbf{273}} \boldsymbol{u_2} \, (\boldsymbol{e_s} - \boldsymbol{e_a})}{\Delta + \gamma(\mathbf{1} + \mathbf{0.34}\boldsymbol{u_2})} \quad (1)$$

where ET_0 is the reference evapotranspiration [mm d^{-1}], R_n is net radiation [MJ m^{-2} d^{-1}], G is soil heat flux [MJ m^{-2} d^{-1}], γ is the psychometric constant [kPa °C^{-1}], e_s is saturation vapor pressure [kPa], e_a is actual vapor pressure [kPa], Δ is the slope of the saturation vapor pressure–temperature curve [kPa °C^{-1}], T is average daily air temperature [°C], and u_2 is mean daily wind speed [m s^{-1}].

To calculate ET_{pan}, pan evaporation data was multiplied by a pan coefficient (k_p) as a correction factor using Eq. (2).

$$ET_{Pan} = k_p \times E_{pan} \quad (2)$$

where ET_{Pan} is pan evapotranspiration, and E_{pan} is A-class pan evaporation [mm d^{-1}].

To calculate k_p, five different equations, Cuenca (1989), Allen and Pruitt (1991), Snyder (1992), Orang (1998), and modified Snyder (Grismer et al., 2002), were used in this study. These models are described as follows.

2.3.2 Cuenca model (1989)

This is a polynomial model based on daily mean relative humidity, wind speed, and upwind fetch of low-growing vegetation. This equation is as follows.

$$k_p = 0.475 - 2.4 \times 10^{-4}u_2 + 5.16 \times 10^{-3}RH + 1.18 \times 10^{-3} \times F - 1.6 \times 10^{-5}RH^2 - 1.01 \times 10^{-6} \times F^2 - 8 \times 10^{-9}RH^2 \times u_2 - 1 \times 10^{-8} \times RH^2 * F \quad (3)$$

where k_p is the pan coefficient, RH is daily average relative humidity [%], and F is upwind fetch distance of low-growing vegetation [m].

2.3.3 Allen and Pruitt model (1991)

This model is expressed generally as follows.

$$k_p = 0.108 - 0.000331u_2 + 0.0422\,Ln(F) + 0.1434Ln(RH) - 0.000631\big(Ln(F)\big)^2 \times Ln(RH) \quad (4)$$

2.3.4 Snyder model

In 1992, Snyder found that the Cuenca (1998) model is a complex model which, under different climatic conditions, produces results different from the original coefficient published by Doorenbos and Pruitt (1977). Snyder proposed a simpler-to-calculate daily k_p as a function of u_2, RH and F. This model was expressed as follows.

$$k_p = 0.482 + 0.24Ln(F) - 0.000376u_2 + 0.0045(RH) \quad (5)$$

Table 1 Accessible online databases

Data Source	Data Type	Usage
NCDC (NOAA)	Air temperature, dew point, and wind speed	Basic
Weatherspark.com	Cloud cover, wind velocity, air temperature and humidity at the airport	Supplementary
Urdu Khan Research Farm	Data of $\boldsymbol{E_{pan}}$, air temperature, sunshine	Supplementary

2.3.5 Modified Snyder model

The Snyder model was modified based on the original data table by Grismer et al (2002). The equation is expressed as follows.

$$k_p = 0.5321 + 0.0249\,Ln(F) - 0.00030u_2 + 0.0025(RH) \quad (6)$$

2.3.6 Orang model

This model was developed by Orang (1998), using interpolation between fetch, and based on the data used to developed FAO-24 k_p. The equation is expressed as follows.

$$k_p = 0.51206 - 0.000321u_2 + 0.002889\,(RH) + [0.031886\,Ln(F)] - 0.000107\,RH\,Ln(F) \quad (7)$$

2.4 Statistical Analysis

A regression analysis was used to determine the accuracy of the results given by the comparison of ET_0 and ET_{pan}. The regression slope (a) was used as the measure of the accuracy, and the coefficient of determination (R^2) was used as the measure of the exactness. Furthermore, according to the suggestion of Jacovides and Kontoyiannis (1995) the root mean square error ($RMSE$), Eq. (8), and the mean bias error (MBE), Eq. (9), were used to evaluate the difference between ET_0 and ET_{pan}. Smaller $RMSE$ and MBE (equal to 0) values indicate better results.

$$\boldsymbol{RMSE} = \sqrt{\frac{\boldsymbol{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{ET_{pan}} - \boldsymbol{ET_0})^{\boldsymbol{2}}} \quad (8)$$

$$\boldsymbol{MBE} = \frac{\boldsymbol{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{ET_{pan}} - \boldsymbol{ET_0}) \quad (9)$$

where $\boldsymbol{RMES}$ is the root mean square error [mm d^{-1}], $\boldsymbol{MBE}$ is mean bias error [mm day^{-1}], and $\boldsymbol{n}$ is a number of data points.

3. RESULTS

3.1 Daily Variation of Metrological Variables

The climate conditions in the study area were semi-arid with a total annual rainfall of almost 356 mm, approximately occurring in the period from December to April in 2009. The air temperature ranged between 0.5 to 37 °C throughout the course of the year. Daily average temperature increased gradually from January onwards until August. The extremely high daily average temperature of 29 °C was recorded in July, while the lowest temperature occurred in December. See Fig. 2a.

The relative humidity ranged from 7% to 97% throughout the course of the year. The lower daily average rate was recorded in the period from May to November, almost 20%, while the extreme lowest rate of below 20% was recorded during the period from June to August. The highest rate occurred in December. See Fig. 2c.

Net radiation was estimated using sunshine data. The net radiation showed the highest rate of above 15 MJ m^{-2} d^{-1} in the period of June and July. See Fig. 2d.

The study area was exposed to two different conditions considering wind speed throughout the course of the year.

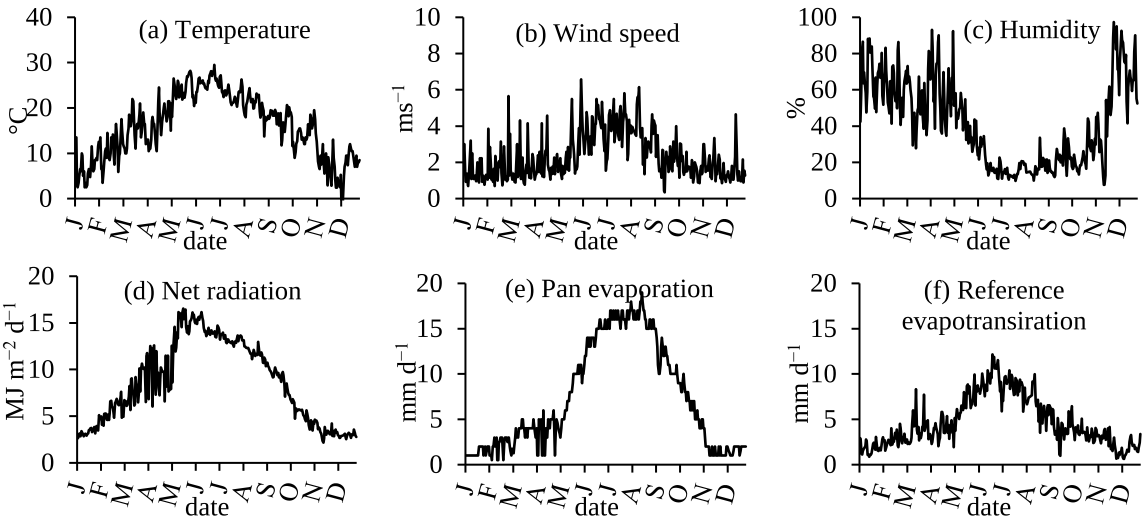

Fig. 2 Daily average meteorological variables in the period from June to December in a course of a year: (a) wind speed, (b) air temperature, (c) relative humidity, (d) net radiation, (e) pan evaporation, and (f) FAO-56PM evapotranspiration.

The wind speed formed two distinguished periods, which are called windy and light-windy seasons in this study. The period from June to September was recorded with the wind speed ranging between 1.2 to 6.6 m s^{-1}, with daily average of 3.5 m s^{-1}. The peak occurred in June at above 6 m s^{-1}. See Fig. 2b. Therefore, the period from June to September is known as the windy season (120-day winds), with relatively strong wind speed. While the rest of the year was exposed to a light wind speed with the daily average speed of 1.5 m s^{-1}.

The E_{pan} data was measured directly at the site. In the period from October to May, E_{pan} was measured below 5 mm d^{-1}. While in the period from June to September, the daily average E_{pan} ranged from 5 to above 15 mm d^{-1}, with the peak occurring in August at above 15 mm d^{-1}. See Fig. 2e.

The ET_0 was estimated using the FAO-56PM method. The rate of ET_0 was extremely high, above 10 mm d^{-1} during the windy season. See Fig. 2f.

In the west region of Afghanistan, in the period from June to September, extreme climatic data out of the experienced range, such as high air temperature, low relative humidity and relatively strong wind speed, were recorded. While during the rest of the year, they were almost within the normal range of the climatic variables. To discuss the error of ET_0, ET_{pan} was selected for comparison. Therefore, there was a chance to analyze the difference between ET_0 and ET_{pan} throughout the course of the year.

4. DISCUSSION

4.1 Comparison between Daily ET_0 and ET_{pan}

Daily average ET_{pan} was compared with ET_0, as shown by Fig. 3. ET_{pan} was estimated using different k_p calculated with different models. ET_{pan} calculated using the modified Snyder k_p was well correlated, with regression coefficient (R^2) value of 0.87, among the explored models. While the sequential performances of the other models were as Cuenca > Orang > Snyder > Pruitt, as shown in Figs. 3b to 3e, respectively.

The statistical indices $RMSE$ and MBE shown in Fig. 4a depict that the modified Snyder model yielded the smallest total $RMSE$ of 1.7 mm d^{-1} with MBE of 0.8 mm d^{-1} throughout the course of the year. While the sequential error of the other models was Orang < Cuenca < Snyder < Pruitt. The positive MBE revealed that the ET_0 is overestimated throughout the course of the year.

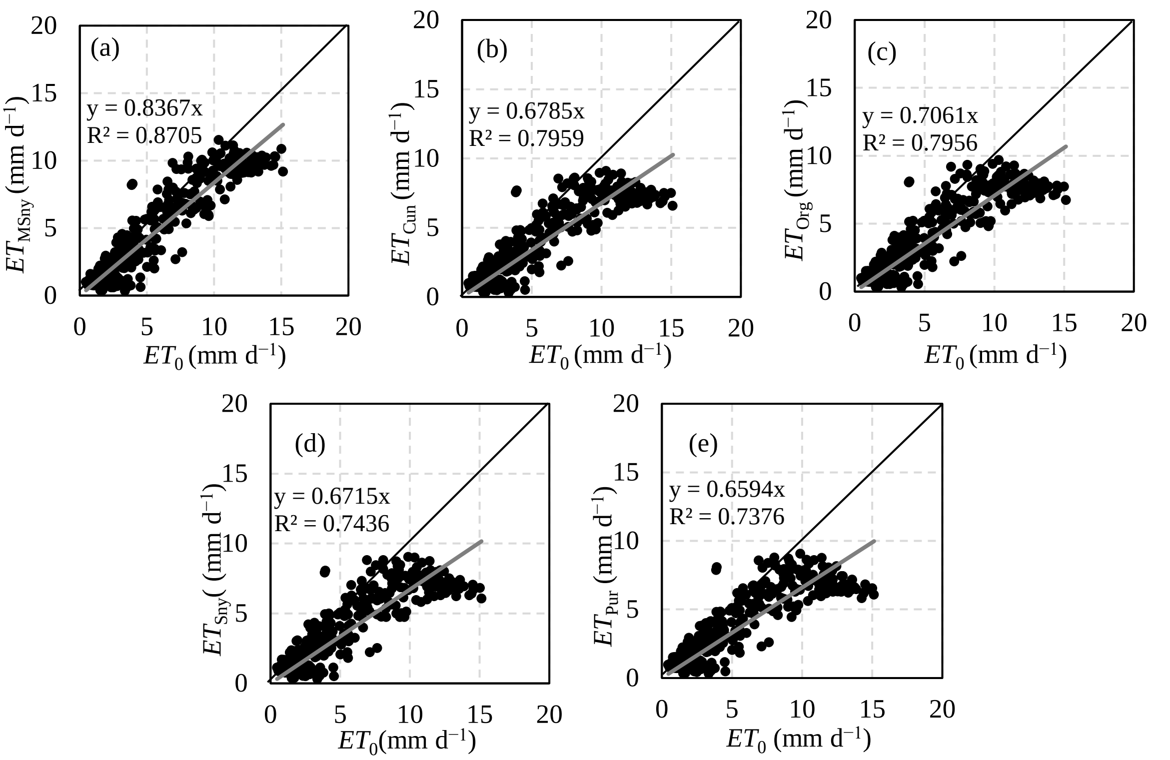

Fig. 3 Comparison of daily average ET_0 with ET_{pan}; (a) ET_{pan} calculated with k_p proposed by Grismer et al. (2002); (b) ET_{pan} calculated with k_p proposed by Snyder; (c) ET_{pan} calculated with k_p proposed by Allen and Pruitt; (d) ET_{pan} calculated with k_p proposed by Cuenca; and (e) ET_{pan} calculated with k_p proposed by Orang.

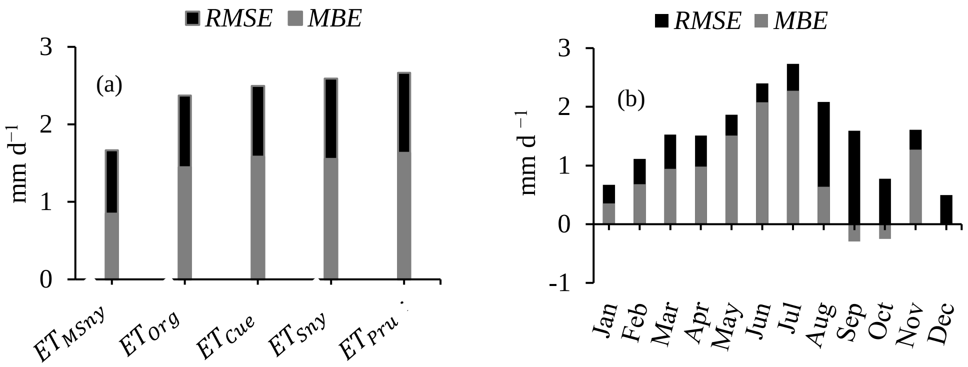

Fig. 4 Error from (a) total error from the difference between ET_0 and ET_{pan} which were estimated using explorered models; and (b) monthly error from the difference between ET_0 and ET_{pan} which was estimated using the modified Snyder model.

Table 2 Yearly correlation value between error and climatic variables

Model	$\boldsymbol{RMSE}$ mm d^{-1}	Correlation value (r)			
		$\boldsymbol{u_2}$	$\boldsymbol{T}$	$\boldsymbol{RH}$	$\boldsymbol{R_n}$
$\boldsymbol{ET_{MSny}}$	1.7	0.6	0.4	−0.3	0.3

The modified Snyder model was the best to estimate ET_{pan} using E_{pan} data. Other researchers already confirmed this, especially under semi-arid conditions. Therefore, here in this paper, the ET_{pan} that was produced using the modified Snyder k_p was selected to analyze the difference between ET_0 and ET_{pan}.

The monthly average error produced by the differentiation of ET_0 and the modified Snyder ET_{pan} are shown in Fig. 4b. The higher $RMSE$ of above 1.5 mm d^{-1} occurred in the period from June to September, with the highest value of above 2.5 mm d^{-1} occurring in July. Although, the order of error was not so small in the rest of the course of the year. However, during the windy season, the highest error occurred. This implies that the windy season is critical for accurate estimation of ET_0 using a theoretical model such as the FAO-56PM model.

4.2 Relationship between Climatic Variables and $\boldsymbol{RMSE}$

The correlation coefficient (r) was used to analyze the effect of the climatic variables on the error of ET_0.

During the period from spring to fall season, the rise of temperature which depends on solar radiation is a common phenomenon in those areas exposed to semi-arid conditions. On the other hand, during this period relative humidity reaches its lowest rate. However, in the case of wind rate, such a common sense that the wind rises during the period from spring to fall is not common. This is a typical and unique case, occurring in the west region of Afghanistan and the eastern part of Iran.

The results showed that in the period from May to October the rate of E_{pan} and ET_0 were larger, with an average value of approximately 7 mm d^{-1} and peak of above 10 mm d^{-1}. While during the rest of the year, the average value was below 5 m d^{-1}. As well, the error from the differentiation of ET_{pan} and ET_0 was getting larger during this period. Experimentally, we found that the error highly correlated with the wind speed. This can be confirmed with the values listed in Table 2. The u_2 with r value of 0.6 showed the strongest correlation compares to the other three variables. The sequential correlation of other variables was $T > R_n$ & RH. This implies that the higher the wind speed, the larger the ET_0 as well as the difference between ET_0 and ET_{pan}. Therefore, it could be confirmed that this kind of error becomes larger when ET_0 becomes larger than 10 mm d^{-1} in the study region.

5. CONCLUSIONS

Optimal estimation of ET_0 is extremely necessary for irrigation scheduling and planning due to the limitation of water resources in the west region of Afghanistan (Herat province). The rate of ET_0 is extremely high during the main crop-growing season. The high rate of ET_0 is related to the extreme climatic data, measured during the period from June to September. While during the rest of the year, the measured climatic data was within the normal range, and the rate of ET_0 was moderate.

To analyze the error of ET_0 , ET_{pan} was selected as an index to make comparisons. At the time when ET_{pan} was calculated, it was found that the modified Snyder method is experimentally best to calculate ET_{pan} nearest to ET_0. Therefore, the difference between ET_0 and ET_{pan} was analyzed. For instance, it was found that wind speed is the most correlated climate data to the differentials of ET_0 and ET_{pan}.

It was confirmed that this kind of error becomes larger when ET_0 becomes larger than 10 mm d^{-1}. Thus, engineers should be careful when calculating ET_0 using the FAO-56PM method, especially in the period of high rate (June to September) in the west region of Afghanistan.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Allen R. G., and Pruitt W. O., FAO-24 Reference Evapotranspiration Factors, J. Irrig. Drain. Eng., vol. 117, Issue 5, pp. 758-773, 1991.

[2] Allen R. G., Luis S., Pereira D. R., and Smith M., Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements-FAO Irrigation and drainage Paper 56," FAO, vol. 300, Issue 9, 1998.

[3] Bandyopadhyay A., Bhadra A., Raghuwanshi N. S., and Singh R., Temporal Trends in Estimates of Reference Evapotranspiration Over India, Int. Journal of Hydrologic Engineering, vol. 14. Issue 5, pp. 508-515, 2009.

[4] Conceição M. A. F., Reference Evapotranspiration Based on Class A-pan Evaporation, Scientia Agricola, vol. 59, Issue 3, pp. 417-420, 2002.

[5] Cuenca R. H., Irrigation System Design: An Engineering Approach, Prentice-Hall, Englewood Cliffs, vol. 552, 1989.

[6] Chiew F. H. S., Kamaladasa N. N., Malano H. M., and McMahon T. A., Penman-Monteith, FAO-24 Reference Crop Evapotranspiration and Class-A pan Data in Australia, Agricultural Water Management, vol.28, Issue. 1, pp. 9-21, 1995.

[7] Chen D., Ge Gao, Chong-Yu Xu, Jun Guo, and Ren G., Comparison of the Thornthwaite Method and Pan Data with the Standard Penman-Monteith Estimates of Reference Evapotranspiration in China, Climate Research, vol. 28, Issue 2, pp. 123-132, 2005.

[8] Doorenbos J., Guidelines for Predicting Crop Water Requirements, FAO Irrigation and Drainage Paper 24, pp. 15-29, 1997.

[9] Frevert D. K., Hill R.W., and Braaten B.C., Estimation of FAO Evapotranspiration Coefficients, Journal of Irrigation and Drainage Engineering, vol. 109, Issue 2, pp. 265-270, 1983.

[10] Gundekar H. G., Khodke U. M., Sarkar S., Evaluation of Pan Coefficient for Reference Crop Evapotranspiration for Semi-Arid Region, Irrig Sci., vol. 26, pp. 169–175, 2008.

[11] Ganji H., Rahmany A., Narioka H., Kondo T., and Kajisa T., Effect of the 120-day Winds on Agriculture and Environmental Condition in Herat, Afghanistan, Brisbane, Australia. 4th Int. Conf. on Geotechnique, Construction Materials and Environment, 2014.

[12] Ganji H., Rahmany A., Narioka H., Kondo T., and Kajisa T., Comparison of the Crop Water Need Between Actual Wind Condition and Zero Wind Simulation; Wind Velocity Within 24-Hour Interval in Herat, Afghanistan, Tokyo University of Agriculture, 20th Int. Conf. on ISSAAS, 2014.

[13] Ganji H., Kajisa T., Kondo M., and Rostami B., Re-Examining the Validity of Reference Evapotranspiration in Herat Afghanistan, Int. Journal of GEOMATE, vol. 12, Issue 30, pp. 61-66, 2017.

[14] Gavilan P., Lorite I. J., Tornero S., and Berengena J., Regional Calibration of Hargreaves Equation for Estimating Reference ET in a Semiarid Environment, Agricultural Water Management, vol. 81, pp. 257–281, 2005.

[15] Grismer M. E., Orang M., and Matyac S., Pan Evaporation to Evapotranspiration Conversion Methods, J. Irrig. Drain. Eng., vol. 128, Issue 3, pp. 180-184, 2002.

[16] Irmak S., Haman D. Z., and Jones J.W., Evaluation of Class-A Pan Coefficients for Estimating Reference Evapotranspiration in Humid Location, J. of Irrigation and Drainage

Engineering, vol. 128, Issue 3, pp. 53-159, 2002.

[17] Oudin L., Frederic H., Michel C., Perrin C., Andreassian V., Anctil F., and Loumagne C., Which Potential Evapotranspiration Input for a Lumped Rainfall–Runoff Model? Part 2—Towards a Simple and Efficient Potential Evapotranspiration Model for Rainfall–Runoff Modelling, Hydrology, vol.303, pp. 290–306, 2005.

[18] Orang M., Potential Accuracy of the Popular Non-linear Regression Equations for Estimating Pan Coefficient Values in the Original and FAO-24 Tables, Unpublished Rep., Calif. Dept. of Water Resources, Sacramento, 1998.

[19] Qureshi A., and Sarwar A., Water Resources Management in Afghanistan-the Issues and Options, IWMI, vol. 49, 2002.

[20] Sabziparvar A. A., Tabari H., Aeini A., and Ghafouri, Evaluation of Class A pan Coefficient Models for Estimation of Reference Crop Evapotranspiration in Cold Semi-Arid and Warm Arid Climates, Water resources management, vol. 24, Issue 5, pp. 909-920, 2010.

[21] Steduto P., Caliandro A., Rubino P., and Mechlia N. B., Penman-Monteith Reference Evapotranspiration Estimates in the Mediterranean Region, Proceedings of int. conf. on evapotranspiration and irrigation scheduling, pp. 357-364, 1996.

[22] Sentelhas P. C., and Folegatti M. V., Class A Pan Coefficients to Estimate Daily Reference Evapotranspiration, Revista Brasileira de Eng. Agr. e Ambiental, vol. 7, Issue 1, pp. 111-115, 2003.

[23] Singh P. K., Patel S. K., Jayswal P., and Chinchorkar S. S., Usefulness of Class A Pan Coefficient Models for Computation of Reference Evapotranspiration for a Semi-Arid Region, MAUSAM, vol. 65, Issue 4, pp. 521-528, 2014.

[24] Snyder R. L., Equation for Evaporation Pan to Evapotranspiration Conversions, J. Irrig. Drain. Eng., vol. 118, Issue 6, pp. 977-980, 1992.

[25] Temesgen B., Simon E., Baryohay D., and Kent F., Comparison of Some Reference Evapotranspiration Equations for California, Irrigation and Drainage Engineering, vol. 131, Issue 1, 2005.

[26] Xu C. Y., and Singh V. P., Evaluation and Generalization of Radiation-based Methods for Calculating Evaporation, Hydrological Processes, vol. 14, pp. 339-349, 2000.